Armed Services Technical Information Agency

AD 43241

Reproduced by

DOCUMENT SERVICE CENTER

KNOTT BUILDING, DAYTON, 2, OHIO

UNCLASSIFIED

NAVORD REPORT 3809

DELAY LINE OSCILLATORS

22 DECEMBER 1954

U. S. NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND

DELAY LINE OSCILLATORS

Prepared by:

William S. Carley

ABSTRACT: A delay line oscillator is described the frequency of which is controlled by varying the termination resistance of a delay line. The frequency of oscillation is linear within ± 1% over a 22.8% bandwidth with output voltage variations of ± 0.75 db at a center frequency of 212 kc. Similar performance should be attainable up to at least 20 mc.

U. S. NAVAL ORDNANCE LABORATORY
White Oak, Silver Spring, Maryland

The results of a preliminary investigation into the feasibility of delay line oscillators are given in this report. References are made in the text to the following publications.

References

(a) William S. Carley, NAVORD Report 3759, "Self Compensated Multilayer Distributed Constant Delay Lines"; 1954

(b) William S. Carley, "Self Compensated Multilayer Distributed Constant Delay Lines", Proc. N.E.C. Vol. 9 pp 150-160; 1954

(c) William S. Carley, "Multilayer Distributed Constant Delay Lines" Tele-Tech and Electronic Industries, May 1954, p 74

The investigation was made as part of Foundational Research Task No. FR-29-54. This report is intended for information only and is not necessarily to be used as a basis for action.

JOHN T. HAYWARD
Captain, USN
Commander

H. J. PLUMLEY
By direction

Contents

Illustrations

DELAY LINE OSCILLATORS

I. INTRODUCTION

1. The circuit diagram of a delay line $\lambda/8$ long terminated in a resistance load less than the characteristic impedance of the line and its equivalent circuit is shown in Figure 1. The equivalent circuit may be derived from a Smith Chart as shown in Figure 3. The Smith Chart is normalized about the characteristic impedance Zo thus R $<$ Zo means $\frac{R}{Zo} < 1$ and $X/Zo = o$. The locus of the terminating resistances is AO. The locus of impedances at the input to the line is A'O. The point A (normalized R = 0, X = 0) transforms into A' (normalized R = 0, X = +1). The locus of the impedance at the input of the line is an inductive reactance and a resistance in series. As normalized resistance at the load increases from zero to R = 1 the normalized input impedance starts with R = 0, X = +1 and varies to R = 1, X = 0.

2. The case of a line terminated in a resistance greater than the characteristic impedance is shown in Figure 2. The equivalent circuit is again derived from Figure 3. In this case the locus of the terminating impedance varies from $\frac{R}{Zo} = \infty$ to $\frac{R}{Zo} = 1$ along the line α, O. The input impedance of the line lies along the line α', O. This case is identical with the previous example except that the sign of the reactance is reversed. Because of this similarity in type and because of the practical difficulty of using a very high impedance termination effort was concentrated on the case of Figure 1. A plot of the normalized terminating resistance vs normalized input reactance and resistance is shown in Figure 4. The input reactance is quite linear over the range of normalized terminating resistance of 0.3 to 0.9. The input resistance however is rising rapidly for termination resistances greater than 0.5. This will cause the effective Q of this line when used as a tank circuit to be lowered.

II. DELAY LINE OSCILLATOR CIRCUITRY

3. The large change of input reactance as the termination resistance is varied and the availability of high characteristic impedance delay lines indicated an application of

this phenomena to a variable frequency oscillator tuned by a variation of terminating resistance. Figure 5 shows the circuit diagram of a Colpitts Oscillator. Figure 6 shows the circuit diagram of this oscillator with the tank inductance replaced by a delay line with a variable terminating resistance. The constants of the circuit are shown for a particular line which was $\lambda/8$ long at 212 kc. The capacitances C_1 and C_2 were chosen such that the oscillator tuned to 212 kc with a terminating resistance of 860 ohms keeping $C_2 \doteq 3C_1$. The circuit oscillated over a range of termination resistances of from 0 - 2650 ohms. The upper limit corresponding to $\frac{R}{Zo} = 9.38$. At this point the equivalent series resistance is quite high (about 4700 ohms from Figure 4) such that the losses become too great to sustain oscillations.

4. Figure 7 shows a plot of the frequency of oscillation vs terminating resistance. From this graph it is obvious that the frequency of oscillation is quite linear with change in terminating resistance. One should note that the line is 0.119 λ long at 201.5 kc and 0.153 λ long at 259 kc. The data from Figure 7 was normalized and plotted on a Smith Chart as Figure 8. The actual value of the equivalent resistance of the inductance of Figure 1 at 259 kc is 0.9 normalized or 6300 ohms.

5. Figure 9 shows the amplitude of the unloaded output voltage vs terminating resistance. The output voltage is quite constant over a broad range of terminating resistance.

6. From Figures 7 and 9 we can observe that over a 22.8% bandwidth (208.5 - 259.5 kc) the amplitude is flat within ± 0.75 db with a frequency linearity of 1% with respect to terminating resistance. The reference line is shown dotted on Figure 7. Over narrower limits the frequency is even more linear.

7. The delay line oscillator was tried in the Hartley Circuit, that is, the delay line acting as a variable capacitance as in Figure 2. Although oscillations were obtained there was a tendency of the oscillator to jump frequency, possibly due to operation on several modes. This oscillator should be inferior to the Colpitts version as only coils and a delay line are used; while capacitors and a delay line are used in the Colpitts. The circuit Q would be lower and thus the oscillator would probably have less stability. For this reason no further work was done on this circuit.

8. Using multilayer delay lines of reasonable size it should be possible to increase the center frequency by a factor of about 10 or decrease the center frequency by a factor of about 5. Using special single layer delay lines of the same characteristic impedance it should be possible to increase the center frequency by a factor of about 100. With special line construction and allowing C_1 and C_2 of Figure 6 to be the interelectrode capacitances of the tube it might be possible to extend the oscillating frequency even higher. In any case C_1 and C_2 should be scaled to the frequency of operation.

III. CONCLUSIONS

9. The feasibility of delay line oscillators for a large relative bandwidth has been demonstrated. The variable resistance at the termination of the line may be replaced by electronic circuits. If the characteristic impedance were increased to 10,000 ohms the bandwidth should be increased to about 27% with the same linearity (about 1%) with respect to terminating resistance.

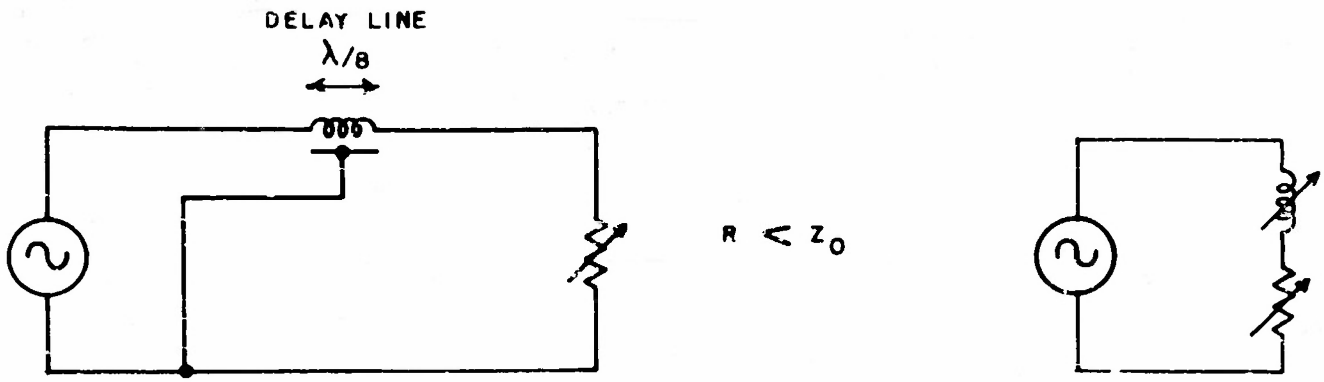

FIG. 1 DELAY LINE TERMINATED IN A RESISTANCE LESS THAN THE CHARACTERISTIC IMPEDANCE AND ITS EQUIVALENT CIRCUIT

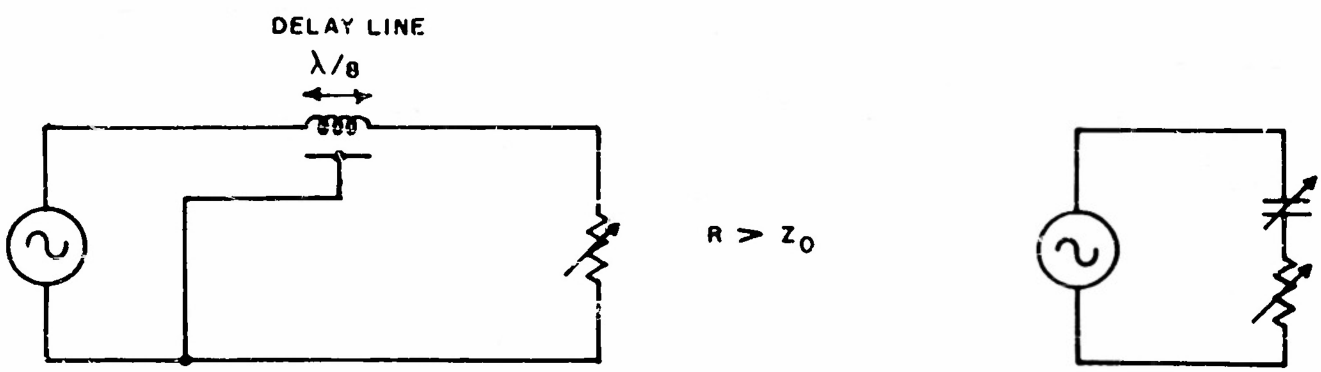

FIG. 2 DELAY LINE TERMINATED IN A RESISTANCE GREATER THAN THE CHARACTERISTIC IMPEDANCE AND ITS EQUIVALENT CIRCUIT

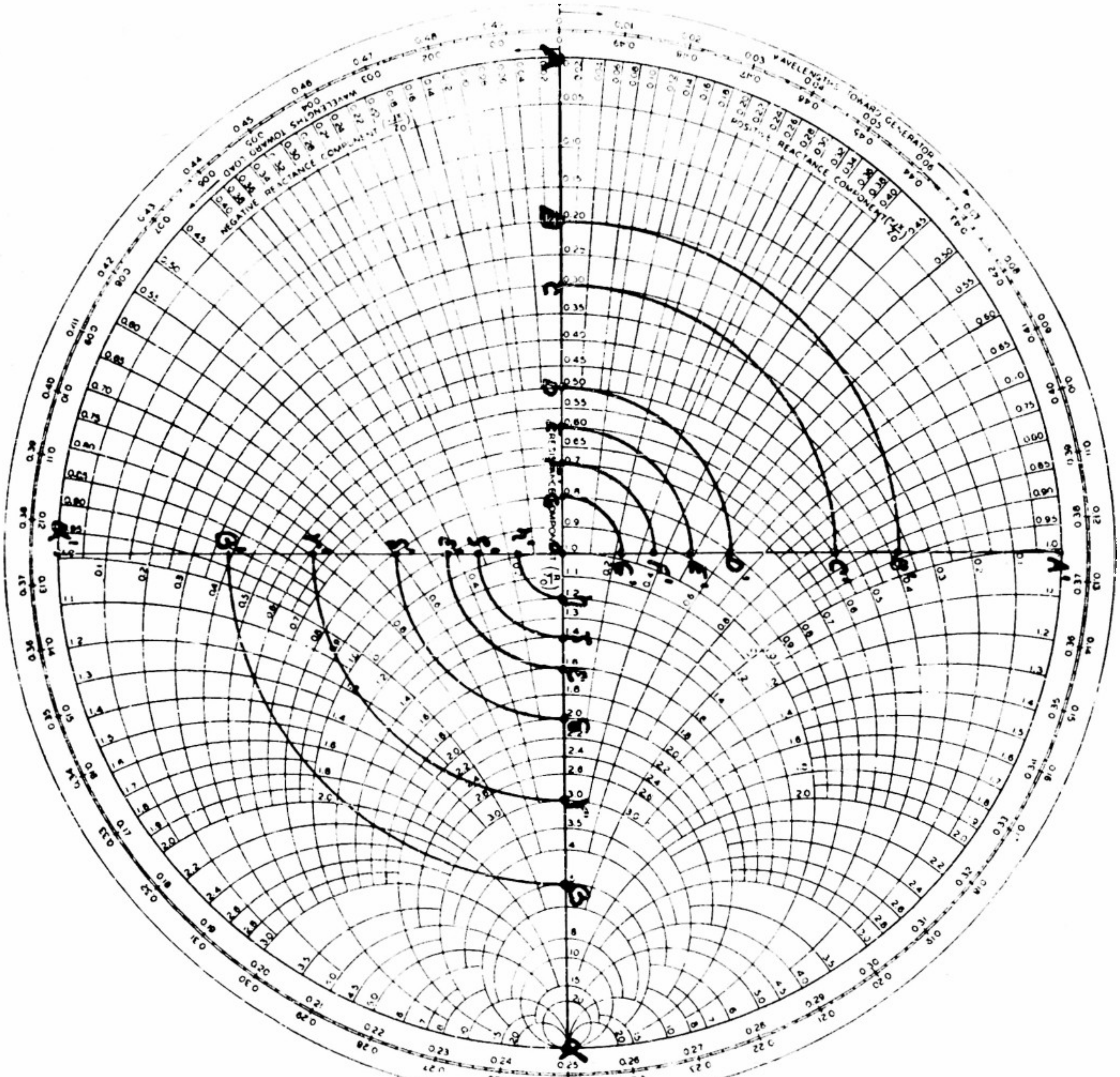

FIG. 3 NORMALIZED INPUT IMPEDANCE vs NORMALIZED OUTPUT RESISTANCE FOR A λ/8 SECTION OF LINE ON A SMITH CHART

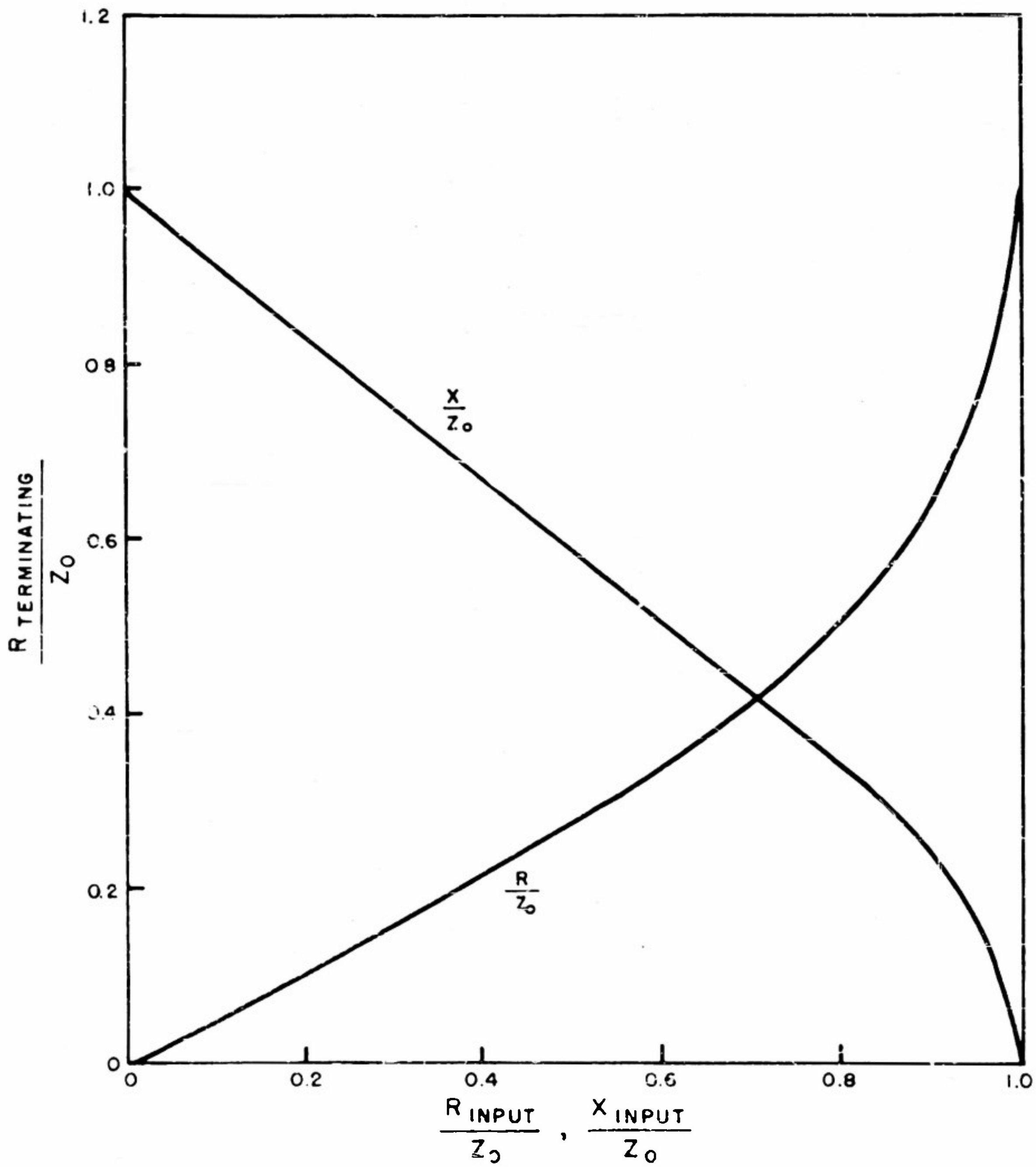

FIG. 4 NORMALIZED TERMINATING RESISTANCE
VS
NORMALIZED INPUT REACTANCE AND RESISTANCE

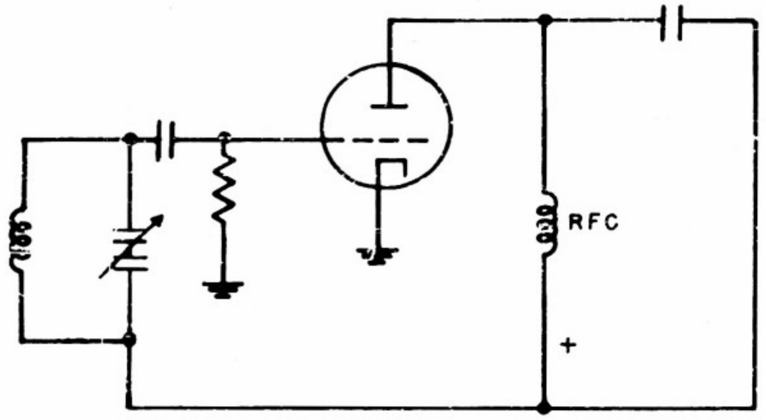

FIG. 5
COLPITTS OSCILLATOR CIRCUIT DIAGRAM

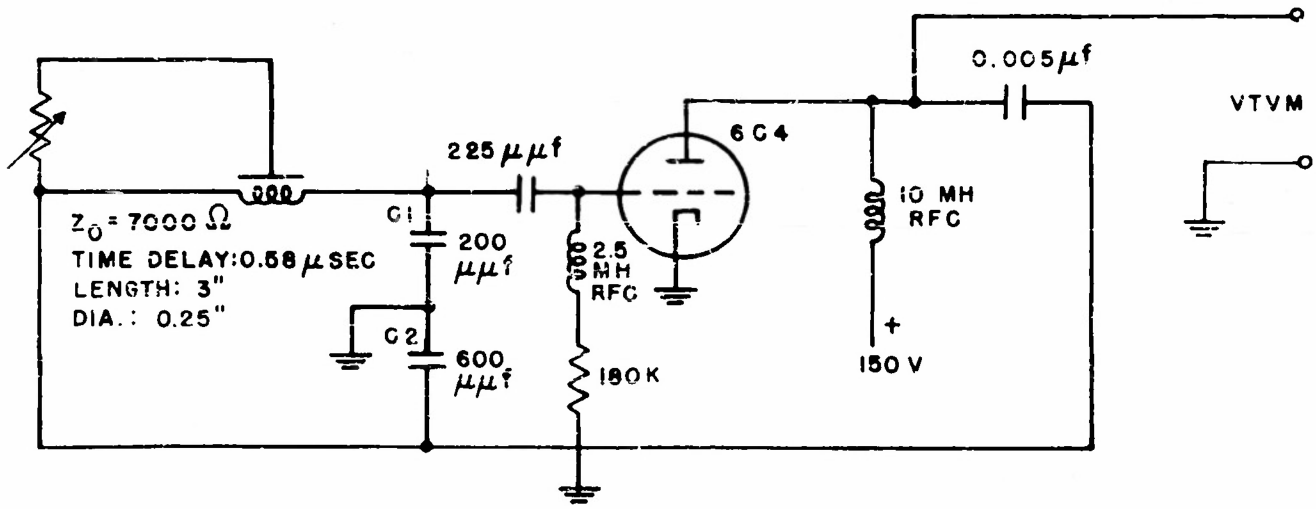

FIG. 6
DELAY LINE OSCILLATOR CIRCUIT DIAGRAM

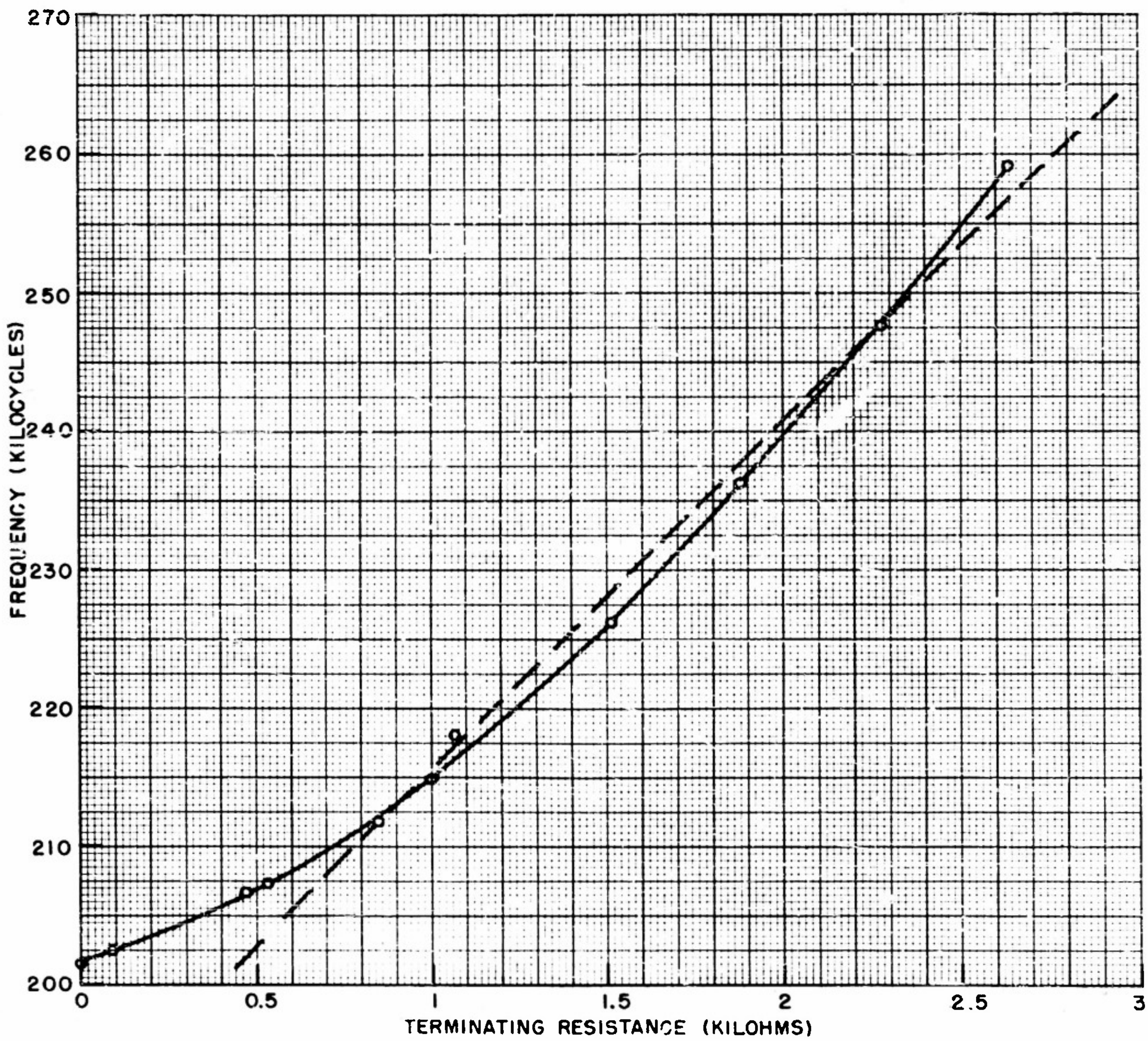

FIG. 7 FREQUENCY vs TERMINATING RESISTANCE FOR DELAY LINE OSCILLATOR

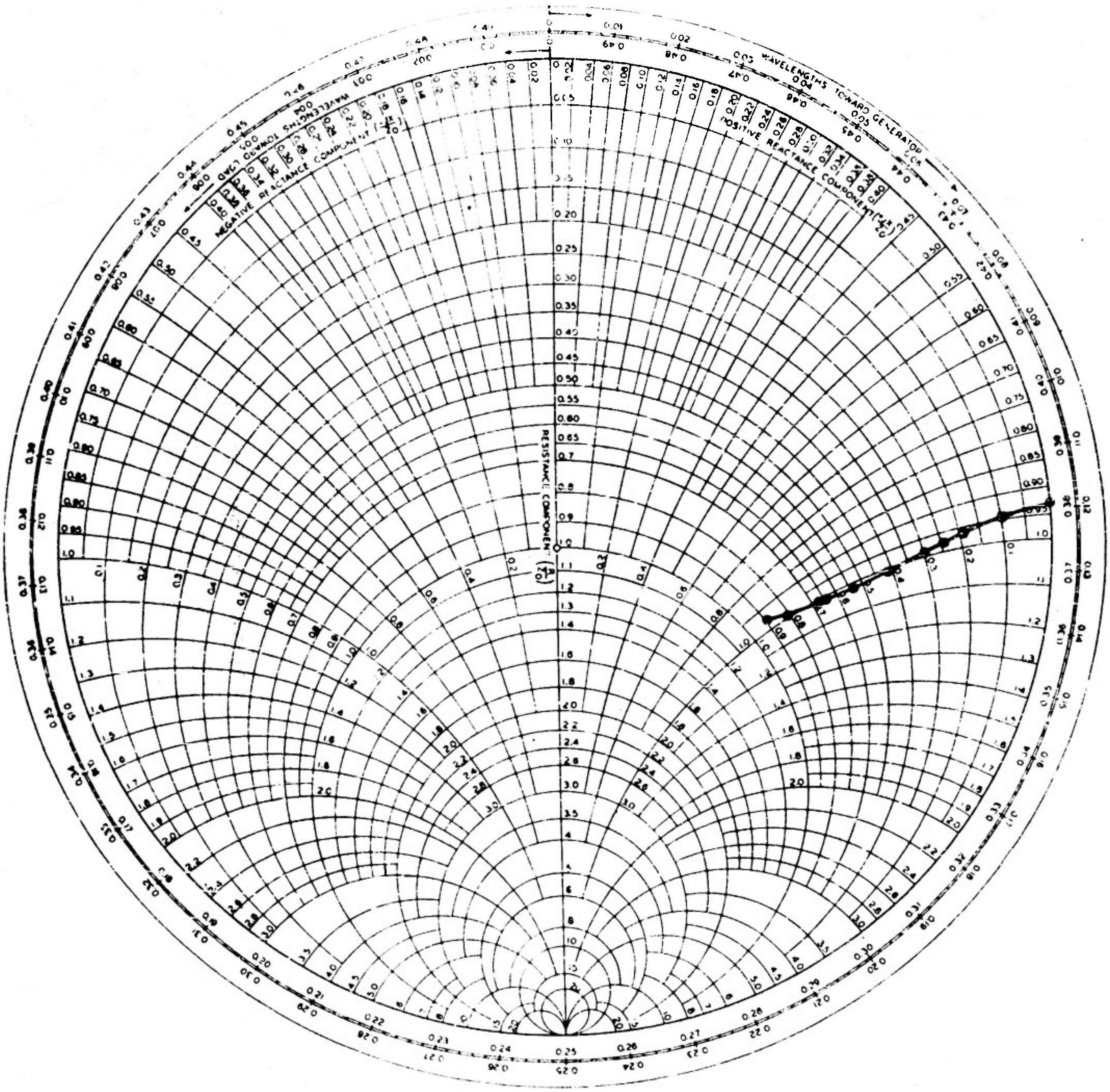

FIG. 8 INPUT IMPEDANCE FOR DELAY LINE OSCILLATOR PLOTTED IN A SMITH CHART

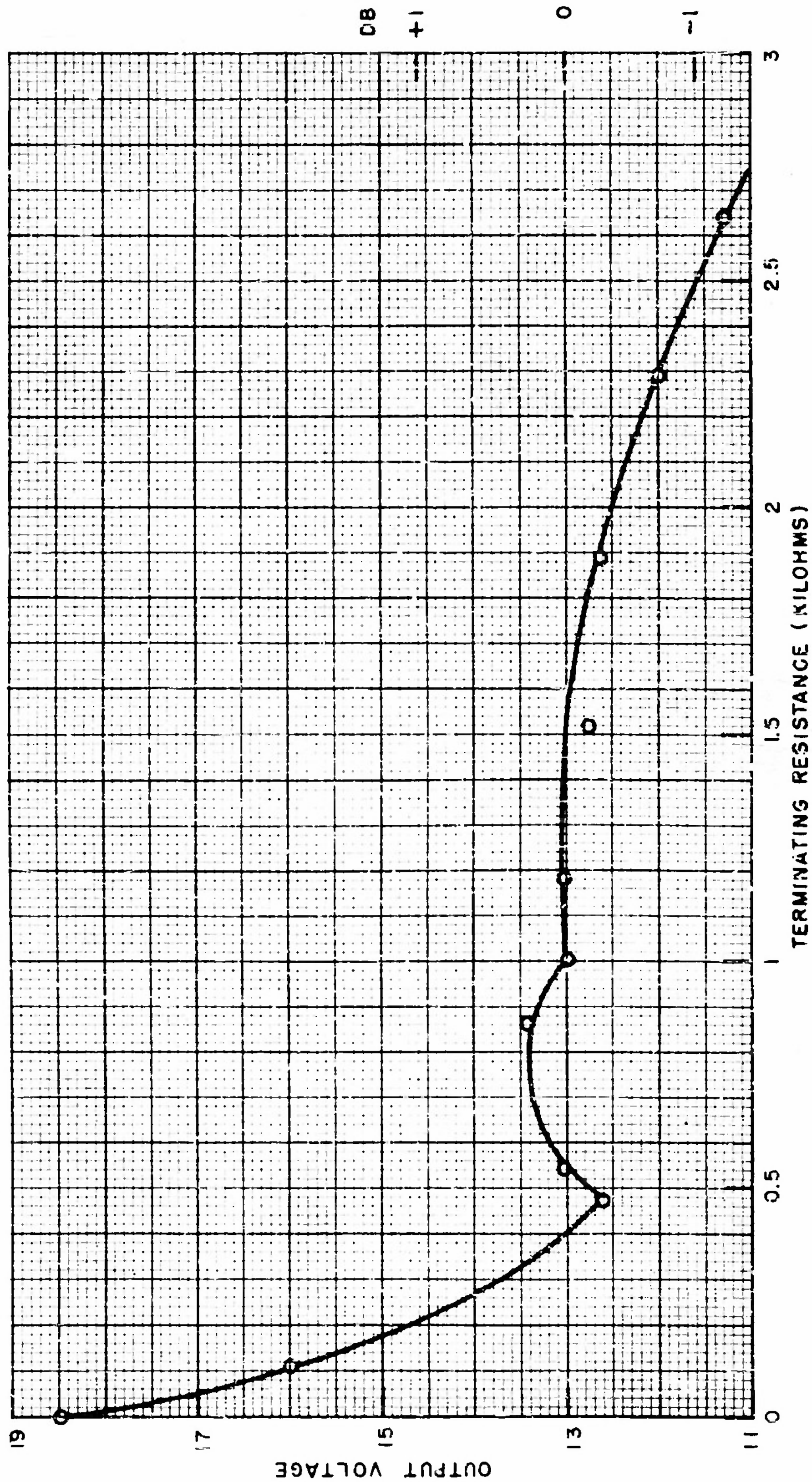

FIG. 9 OUTPUT VOLTAGE vs TERMINATING RESISTANCE FOR DELAY LINE OSCILLATOR